Removal of Water Turbidity by using Aluminum Filings as a Filter Media

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ABSTRACT

The ability of using aluminum filings which is locally solid waste was tested as a mono media in gravity rapid filter. The present study was conducted to evaluate the effect of variation of influent water turbidity (10, 20and 30 NTU); flow rate(30, 40, and 60 l/hr) and bed height (30and60)cm on the performance of aluminum filings filter media for 5 hours run time and compare it with the conventional sand filter. The results indicated that aluminum filings filter showed better performance than sand filter in the removal of turbidity and in the reduction of head loss. Results showed that the statistical model developed by the multiple linear regression was proved to be valid, and it could be used to predict head loss in aluminum filings filter and sand filter with R^2equal to 0.94 and 0.968 respectively.

Key words: water treatment turbidity, filtration, aluminum filings, sand .

ازالة عكورة المياه باستعمال برادة الالمنيوم كوسط ترشيح

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الخلاصة

تضمن البحث دراسة امكانية استخدام برادة الالمنيوم كماده مرشحه احادية لازالة عكورة الماء من خلال اختبار كفاءة المرشح لتاثير التغير في عكورة الماء الداخل(10، 20 ،30 وحدة عكورة) ومعدل الجريان (30، 40، 60) لتر/ساعة و ارتفاع الوسط(30 ، 60) سم على مقدار العكورة الخارجة وارتفاع عمود الماء ومقارنتها مع مرشح الرمل التقليدي ولمدة تراوحت بين (0.5 و5 ساعات) . ولقد بينت النتائج ان كفاءة مرشح برادة الالمنيوم كانت اعلى من كفاءة المرشح الرملي كما اظهرت النتائج ان ارتفاع عمود الماء لبرادة الالمنيوم كان اقل مماهو عليه في حالة المرشح الرملي بحوالي (8-32%). كما استخدمت البيانات من اختبارات الترشيح لبناء نموذج إحصائي لدراسة تاثير المتغيرات المدروسة على ارتفاع عمود المياه باستخدام الانحدار الخطي المتعدد ومن خلال مقارنة النتائج الحقلية مع تلك التي تم الحصول عليها باستخدام النموذج الاحصائي تم التوصل الى كفاءة النموذج الاحصائي بحيث يمكن استخدامه للتنبؤ باتفاع عمود المياه في مرشح الألمنيوم ومرشح الرمل حيث كانت R^2 تساوي 0.94 و 0.968 على التوالي.

الكلمات الرئيسة : معالجة المياه ،عكورة، ترشيح ، برادة الالمنيوم، رمل.

1. INTRODUCTION

One of the many challenges faced in developing world is the issue of waste management. According to the US Army Corps. of Engineers, **USACE, 1995.** “Aluminum has excellent corrosion resistance in a wide range of water and soil conditions because of the tough oxide film that forms on its surface.

The Aluminum Association, 2005. states, “Unless exposed to some substance or condition which destroys this protective oxide coating, the metal remains resistant to corrosion. Aluminum is highly resistant to weathering, even in many industrial atmospheres, which often corrode other metals. It is also resistant to many acids.”

The surface water is the main source for water supply in most developing countries and in many parts of the world, river water that can be highly turbid, is used for drinking purposes. Access to improved drinking water is unavailable to an estimated 884 million people in the world most of who live in rural dispersed and often remote communities in developing countries **WHO/UNICEF, 2010**. As identified by the United States Environmental Protection Agency (USEPA), turbidity is a measure of the cloudiness of water; it is used to indicate water quality. The main problem in using surface water as a source of water supply is high concentration of clay and suspended solids, organic compounds and disease-causing microorganisms (such as viruses, parasites and some bacteria) which can cause symptoms such as nausea, cramps, diarrhea, and provide food and shelter for pathogens **,WHO, 2007**. The permissible limit for treated water in Iraq is 5 NTU **, according to Iraqi standards, 2001.**

Filtration is the most common method to remove clay and suspended solids, in filtration process, water is purified by passing through a bed of porous media which cause the retention of suspended matters within it. Although the existing granular filter media such as sand is sufficient to treat turbid water, discovering an alternative filter media from local source is also highly essential and are becoming popular since it will help to reduce the cost of treatment, as it can be processed and produced locally, and of their better removal efficiency as compared to conventionally used media **Jusoh et al., 2006** .

Jasim ,1977 examined the efficiency of rice shell and crushed date stone as an alternative materials due to their availability in large quantities in Iraq, and concluded that these materials can be utilized as a filtering media rather than as animal feed.

Al-Anbari,1997 selected suitable and durable locally filter media. The author tested the lightweight material like (porcelanite rocks and brunt kaolinite), and a heavy weight media like (goethite rock). For single media filter, porcelanite and kaolinite gave better results in turbidity removal efficiency and net water product value than sand medium.

Tang et al., 2006 evaluated the performance of crumb rubber as filtering material for ballast water treatment. It was found that crumb rubber is an excellent filter media for downward granular media filters in comparison to traditional granular media filters, a substantial reduction in turbidity was achieved, no clear relationship between filter depth and turbidity removal efficiency was found, higher filtration rate resulted in a lower turbidity removal efficiency.

Juosh et al.,2006 used palm shell as single and dual media filter. Palm shell is one of the industrial wastes that are abundantly available. Result suggests that all the filters are capable of producing water with acceptable turbidity unit (<1 NTU).

Nasser, 2010 investigated the ability of using crushed glass solid wastes as mono media with sand in the filtration process. The results indicated that the glass filters had better turbidity removal efficiencies with a reduction of about 50% in washing water was required to wash the glass filters. Also glass filters were slower in the development of head losses.

Shubir, 2011 investigated the ability of using crushed plastic solid wastes, whose density less than that of water, in water filtration. The results indicated that the single plastic filters and the dual filters produced water of the same (high) quality as the sand filter. Also, it showed that plastic filters were slower in development of head losses and they have longer running time than the sand filters. The main objective of this work is to evaluate the performance and effectiveness of sand filters by utilizing aluminum filings as filter media which is a locally available solid waste material .

2. EXPERIMENTAL WORK

The experimental work of this study was based upon the use of packed bed filtration pilot plant for the removal of water turbidity by using different types of solid wastes as a filter media (aluminum filings and sand) at different flow rate , initial turbidity and bed height The experimental apparatus is shown in **Fig. 1.** It consisted of two galvanized cylindrical tanks of capacity 70 L; Perspex filter column of 7.5 cm inner diameter and 150 cm height designed and built to run with down flow direction according to **,AWWA Manual, 2000**. Calibrated flow meter was used to control the flow, with flow range of (10-100 l/hr). Four glass tubes fitted on a board was used to record the height of water at different depths for each filter. Two types of filter media were used aluminum filings as a locally available solid waste and conventional sand filter media, **Table 1.** show the characteristics of these filter media.

The aluminum filings used is flat shaped, 100% recycled from solid wastes. It is washed and sieved to obtain grain sizes of (0.6-1) mm in diameter

The filter was operated on the principle of constant flow rate and variable head loss mode. 70 liter of turbid water (10, 20, or 30 NTU) was pumped through the flow meter at different flow rates (30, 40, or 60 l/hr). This flow range was chosen to simulate the rapid filter flow rate in most water treatment plants. Two different bed heights were studied 30 and 60 cm for each experiment. Samples of the filtered water were taken every (30 minutes) during the run of 5 hours. The water level in the piezometers was recorded at the starting of each run and at fixed time intervals (each 30 minutes) to determine the head loss along the filter depth.

Turbidity was measured by a portable turbidity meter (Hanna instruments, HI 93703). The recorded level had accuracy of (0.5) NTU. The values of the available head were read by using the piezometers at fixed time intervals. PH value was measured for every sample and it was found that it was within the PH value for tap water.

Large quantity of kaolin was added to 10 liter preparation tank, shaken well, and left for 15 min in order to let larger suspended solids settle under the influence of gravity, and to obtain turbidities of (10, 20 , 30) NTU , then it is transferred to the storage tank. Turbid water (10, 20, 30) NTU from the storage tank was pumped through flow meter at different flow rates (30, 40, 60) l/hr, this flow range was chosen to simulate the rapid filter flow rate to the filter column. The water level in the piezometers were recorded at the starting of each run and at fixed time intervals (each 30 minutes) to determine the head loss along the filter depth. Samples of the filtered water were taken every (30 minutes) during the run of 5 hours. The experimental work was achieved in the Environmental Engineering Department/ Baghdad University.

3. RESULTS AND DISCUSSION

3.1 Effect of Influent Turbidity

Three different influent turbidities were tested in this study (10, 20, and 30 NTU), during each run the flow rate and bed depth were kept constant. **Fig.2** illustrates the effect of influent turbidity on the turbidity removal efficiency. It can be seen from this figure that sand has lower turbidity removal efficiency compared with aluminum filings filter. It is obvious that greater porosity value yield poorer filtrate quality due to smaller available surface area for deposition **, Gronow, 1986**. In this experimental work, best filtrate results were for aluminum filings filter though they had a higher porosity than sand filter. The flat shape for the aluminum filings gave better results due to stability of deposits onto flat surfaces, and not critical deposits onto rounded surfaces as in the case of sand. These results are in good agreement with **Jasim, 1977**; who found that flat shaped grains usually perform better than do rounded or worn grains due to their higher stability of sediments.

3.3 Effect of Flow Rate

The flow rate affects the filtrate quality; it is believed to be due to the increase of interstitial velocity. The interstitial velocity depends on the incoming approach velocity above the filter bed as well as the porosity **, Holdich, 2002**.

Three different flow rates were tested in this study (30, 40 and 60) l/hr. During each run influent turbidity and bed depth were kept constant. **Fig.3** shows the effect of flow rate on turbidity removal efficiency at 10 NTU influent turbidity of each filter type. It can be seen from these figures that when the flow rate increased removal efficiency decreased, and this is in a good agreement with the results of **Mohammed, 1989** and **Degremont, 1991**. At high filtration velocity the retained suspended solids are sheared off from the bed due to the high velocity force **Sundarakumar, 1996**.

3.4 Head Loss Variation with Time

In order to study the head loss across the bed. Piezometers were installed at different depths across the bed. During the filtration process, head loss built up because particles began to fill the void space in the filter media. The head loss development was increased with increase in influent turbidity for all filter media types. **Figs. 4, 5 and 6** illustrate the relation between the head loss with time at different depths for each type of filter media and at10 NTU influent turbidity and 60 cm bed depth. The head loss development for different influent turbidities is shown in **Fig.7**.

At low filtration velocity, the amount of suspended solids captured within the media is lower than the high filtration velocity. So in the case of low filtration velocity, the head loss development is very slow. This phenomenon is common for all media types as can be seen in **Fig. 8**.

For the same operational conditions and for all media types, sand filter showed the higher head loss at different depths than aluminum filings filter. This phenomenon is due to the high porosity of aluminum compared with sand, sustaining a greater load of sediments with lower head losses.

The head loss after five hours of filtration is presented in **Table 2** it can be seen from this table that aluminum filings filter shows less head losses than the sand filter during all runs, filtration rate impacted head loss substantially. Generally, a deeper filter depth and higher filtration rate resulted in a higher head loss.

4. EFFECT OF BED HEIGHT

Two different bed heights were tested in this study (30, and 60) cm, during each run influent turbidity and flow rate were kept constant. Filter depth appeared to have fairly significant influence on turbidity removal efficiency for different initial water turbidity. **Fig.9** shows the effect of depth on the removal efficiency. This can be attributed to the availability of more opportunity for particles to accumulate in higher depth. These accumulated particles act as new collectors until a saturation state is reached.

5. STATISTICAL ANALYSIS

A total filtration data sets (two types of filter media (aluminum filings and sand), two media depth (30 and 60cm) ,three different flow rates (30 , 40 and 60 l/hr), and three different initial turbidities (10 , 20, and 30 NTU) were collected and a analysis by using Multiple regression was performed using excel program for the examination the effects of each parameter on the head loss at the end of five hours run time.

A mathematical equation was introduced to correlate all of the data obtained using a multiple regression technique for aluminum filings filter and for and filter is as follows

For aluminum filings:

$$Head\ loss(X_1) = -28.188+0.0.504\ X_2 +0.0.472\ X_3 + 0.723X_4 \qquad (1)$$

For sand:

$$Head\ loss(X_1)= -19.067+0.568\ X_2+0.344\ X_3+ 0.9083\ X_4 \qquad (2)$$

Where: X_1= head loss
X_2 = flow rate
X_3 = bed height and
X_4 = influent turbidity

The equations fits the experimental data very well with R^2 = 0.94 and 0.968 for aluminum filings and sand filter respectively, as shown in **Fig.10**

6. CONCLUSIONS

1. Aluminum filings filter was efficient in turbidity removal as in sand filters. The maximum turbidity removal efficiency for sand filter was 86% at 40 l/hr filtration rate, while for aluminum filters as 89% at 30 l/hr filtration rate, 10 NTU influent turbidity, and 60m depth.
2. The maximum head loss for sand was 64.7cm,and aluminum filings was 55.7cm respectively at 60l/hr filtration rate, 30 NTU influent turbidity, and 60cm depth at the end of five hours run time.
3. Stability of the sediments in filtration contributed to the shape of the grains forming the filter bed.
4. Filter depth have fairly significant influence on turbidity removal efficiency, a deeper filter depth resulted in a higher head loss.
5. The statistical model developed by the multiple linear regression can be used in predicting head loss in aluminum filings filter and sand filter.

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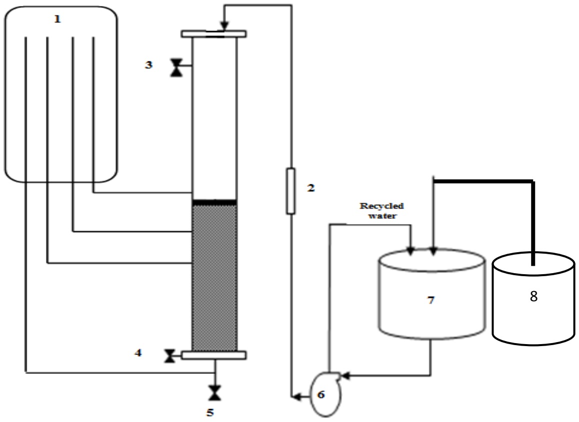


1.Manometer board 2.Flow meter 3.Wash water valve 4.Air valve 5 . Filtered water valve 6.Pump 7.Water tank 8.Preparation tank

Figure1. Schematic diagram of experimental apparatus.

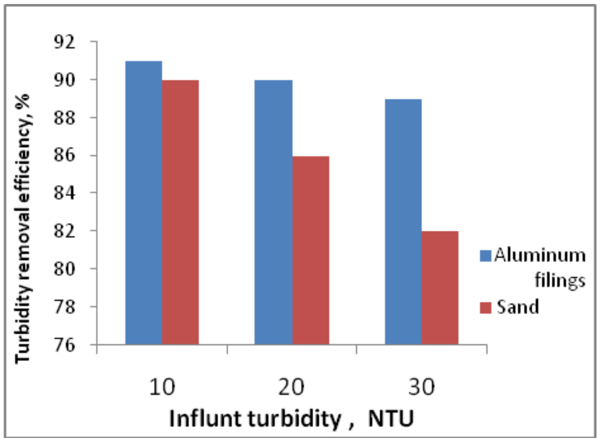
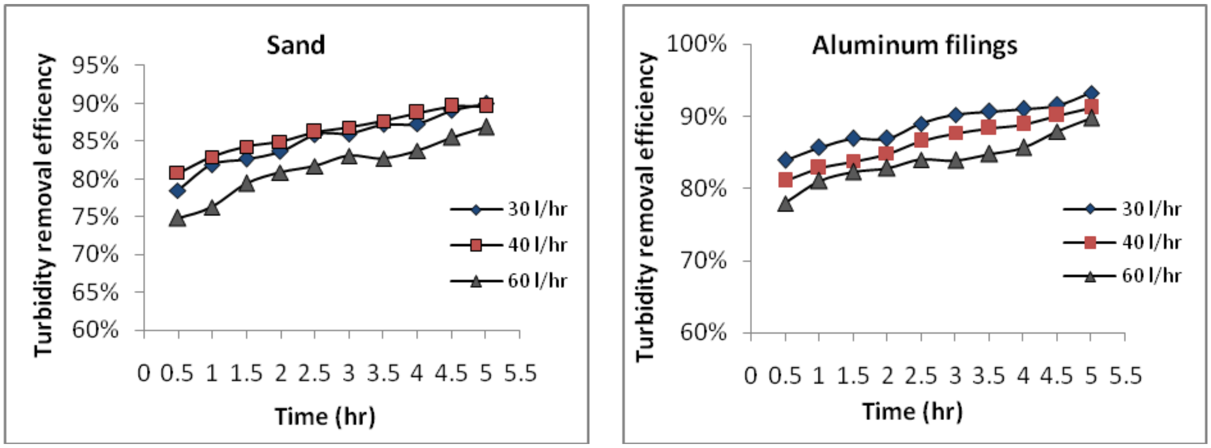
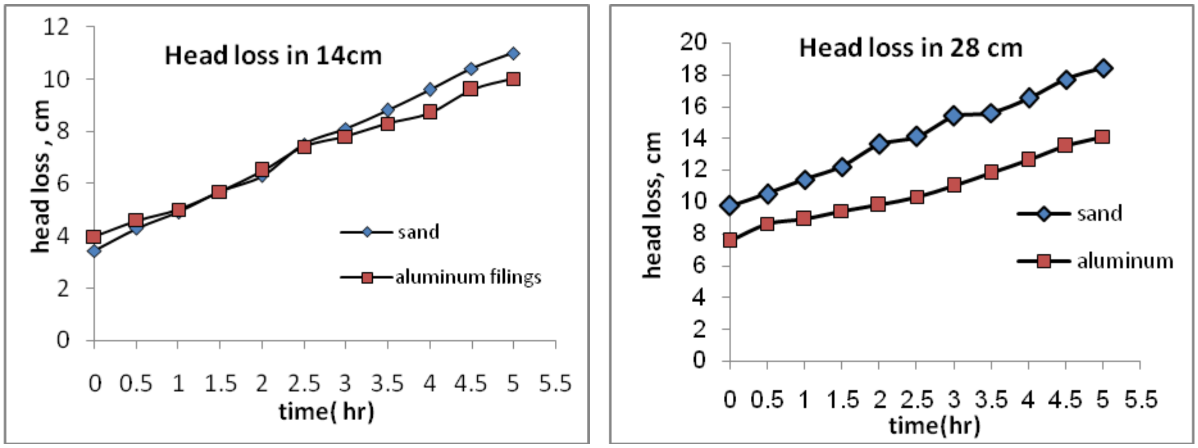


Figure 2. Effect of influent turbidity on the turbidity removal efficiency at bed deptht=30, flow rate 30 lit/hr.



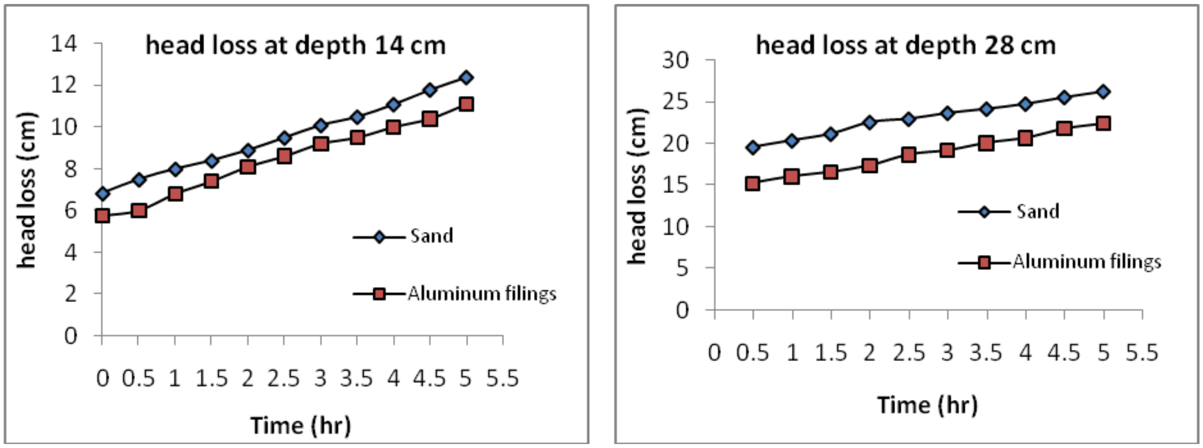
(a) (b)

Figure3. Effect of flow rate variation on turbidity removal efficiency, influent turbidity =10NTU, bed depth=60 cm.



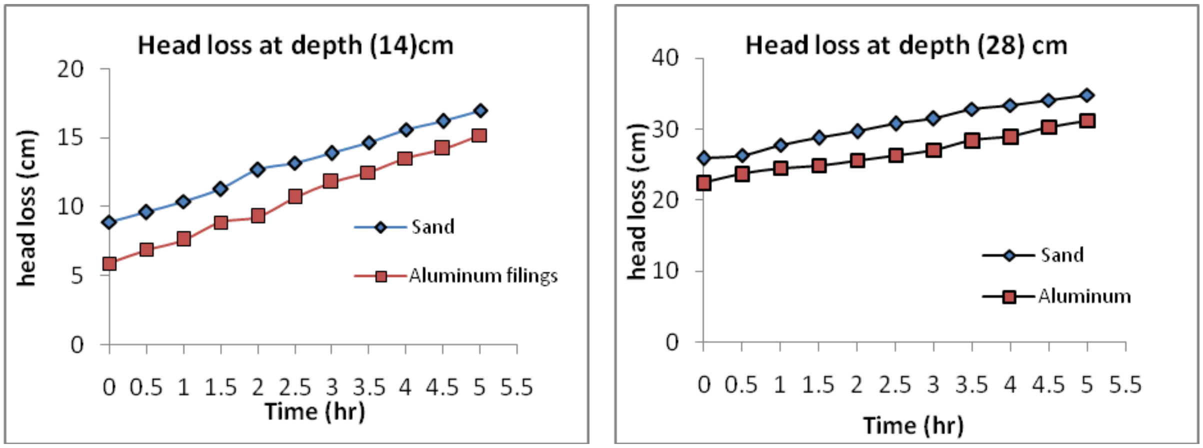
(a) (b)

Figure4. Head loss versus time at different heights of the filter at bed depth 60 cm, flow rate = 30 l/hr, turbidity =10 NTU.



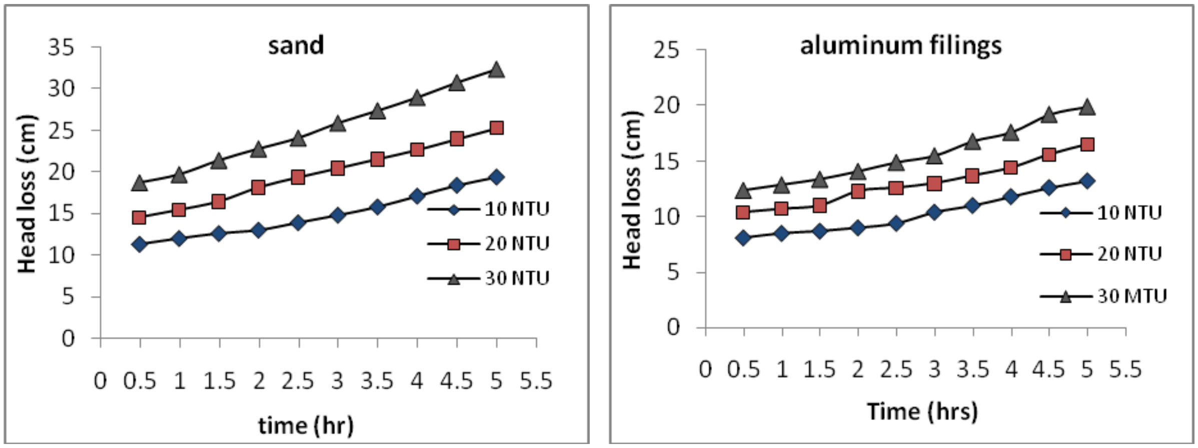
(a) (b)

Figure5. Head loss versus time at different heights of the filters at bed depth 60 cm, flow rate = 40 l/hr, turbidity =10 NTU.



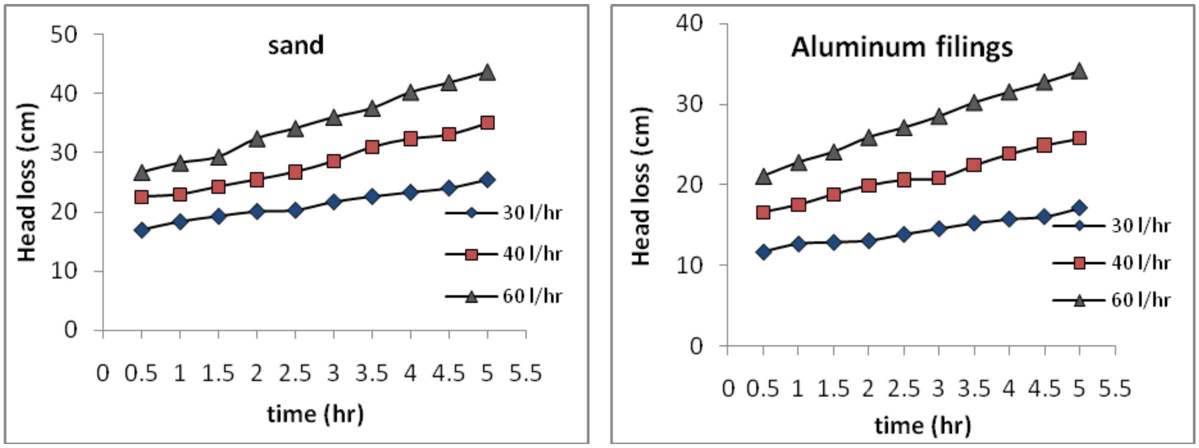
(a) (b)

Figure6. Head loss versus time at different heights of the filters at bed depth60 cm, flow rate=60 l/hr, turbidity=10 NTU.



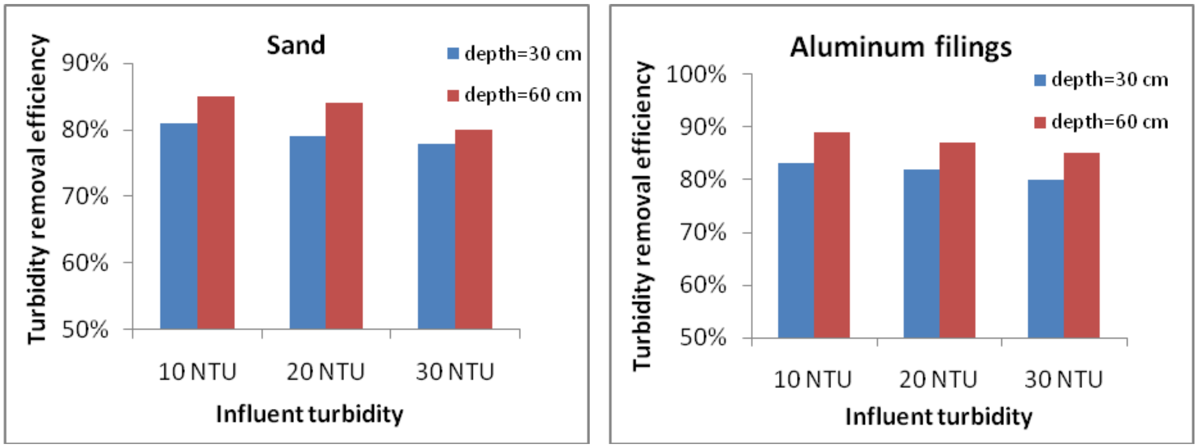
(a) (b)

Figure 7. Head loss versus time at different influent turbidity, flow rate=30 l/hr, filter depth =30 l/hr.



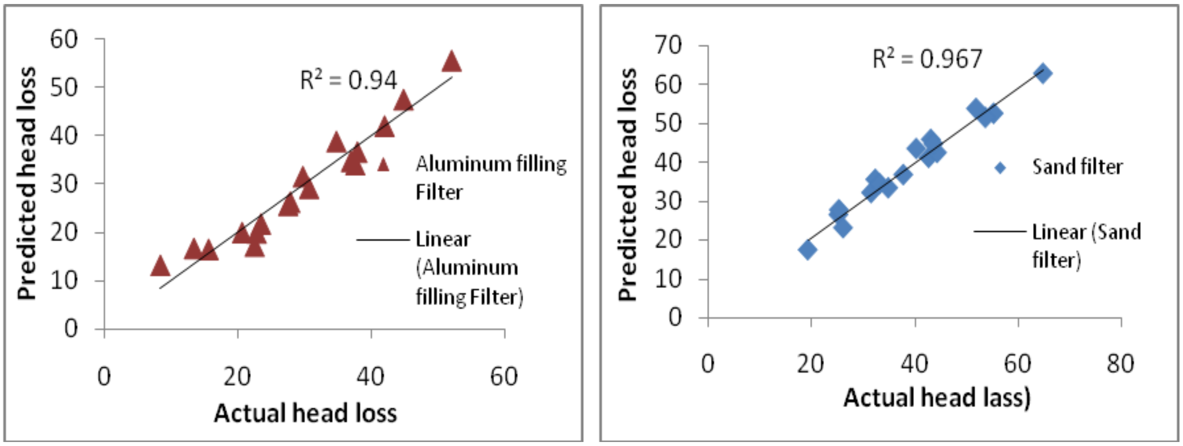
(a) (b)

Figure 8. Head loss versus time at influent turbidity = 10 NTU , bed depth = 60cm and different filtration rates.



(a) (b)

Figure. 9 Impact of bed height on the removal efficiency at different influent and flow rate = 30 l/hr.



(a) (b)

Figure10. Comparison between actual and predicted head loss.

Table 1.Characteristics of filter media.

Media	Specific gravity	porosity	Effective size	Uniform coefficient
Aluminum filings	3.08	80%	0.62mm	1.35
Sand	2.66	37%	0.62mm	1.4

Table 2. Head loss for the two filters.

Flow rate (l/hr)	**Influent Turbidity, NTU**	**Head loss (cm), bed height 30cm**		**Head loss (cm), bed height 60cm**	
		Sand filter	**Aluminum filings filter**	**Sand filter**	**Aluminum filings filter**
30	10	19.4	13.2	25.4	17.2
	20	25.3	16.5	37.8	31.6
	30	32.4	19.9	43.1	34.8
40	10	26.2	16.7	34.9	25.7
	20	31.6	20	44.3	38.9
	30	42.7	26.3	53.6	42.1
60	10	33.2	21.8	43.6	34.1
	20	40.3	29.2	51.8	47.6